Calibration and data processing Biospherical C-Ops of system used on the deployment cruise:
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NAME: Biospherical C-Ops System
S/N: 271(E_s), 272 (E_d), 273 (L_u)

1) Introduction and Summary

The Biospherical C-Ops System is a matched set of 3 multispectral radiometers and a profiling frame, which also contains instruments to measure temperature and pressure. On the profiler, one radiometer is pointed upward, to measure downwelling irradiance (E_d), while another is pointed downward, to measure upwelling radiance (L_u). The third radiometer is mounted on the ship, to measure incoming solar irradiance (E_s). The profiling package is deployed behind the ship, and free-falls at approximately 15-30 cm/sec.

The three radiometers have a spectral range from 300 to 900 nm, with 19 wavebands each: 305, 320, 340, 380, 395, 412, 443, 465, 490, 510, 532, 555, 565, 625, 665, 683, 710, 780, 875 nm. The upwelling radiance radiometer substitutes a broad natural chlorophyll fluorescence sensor (27nm FWHM, centered at 683nm) for the 875 nm sensor. All other wavelengths are 10nm FWHM.

Table 1: Optical sensitivity. Expressed as Noise Equivalent Signals at 5 Hz for radiance (NER: µW /(cm2 nm sr)) and irradiance (NEI: µW/(cm2 nm)) (reproduced from C-Ops Manual):

Channel	**NER**	**NEI**
320 nm	2.9×10^{-6}	9.0×10^{-5}
395 nm	5.0×10^{-6}	6.9×10^{-5}
490 nm	1.8×10^{-6}	2.3×10^{-5}
683 nm	9.9×10^{-7}	1.1×10^{-5}
780 nm	6.8×10^{-7}	8.0×10^{-6}

2) Calibration/Maintenance

2.1) Manufacturer calibrations/coefficients

The instruments were manufactured late in 2011, and were most recently calibrated Apr 26, 2017 at BSI's San Diego facility.

2.2) Self calibration methods and results

The radiometers were not calibrated by the users.

3) Deployment

3.1) Measurement methods

Profiles were made at several stations when conditions were favorable. They were also made more regularly toward the end of the campaign, when the Satlantic Hyperpro was non-functional. Unfortunately, time was not sufficient to have both radiometer systems deployed at the same station. The deployment coincided with IOP measurements. A rosette was also used to collect water for filtration.

Before each station, dark current measurements at each of the three gain stages and a pressure tare were made by capping the sensors and running the dark current procedure through the μProfile software (C-Ops manual). The ship would be positioned such that the sun was over the stern, then all profilers would be cast into the water and positioned 15 to 25 meters behind the ship before profiles were made. A burst of the ship's propeller was sometimes needed to establish the distance between the ship and the profiler.

A series of free-fall casts would begin, using the multi-cast method (Zibordi, et al 2011). The solar reference radiometer was mounted on a telescoping mast on the 01 deck, far from other superstructures so that they did not interfere with the measurement of E_s.

3.2) Package design

The profiling package is designed to maintain a stable, vertical orientation through the water when in free-fall. It has adjustable flotation and weighted disks, which allow the user to trim the package to achieve <30 cm/sec descent rate.

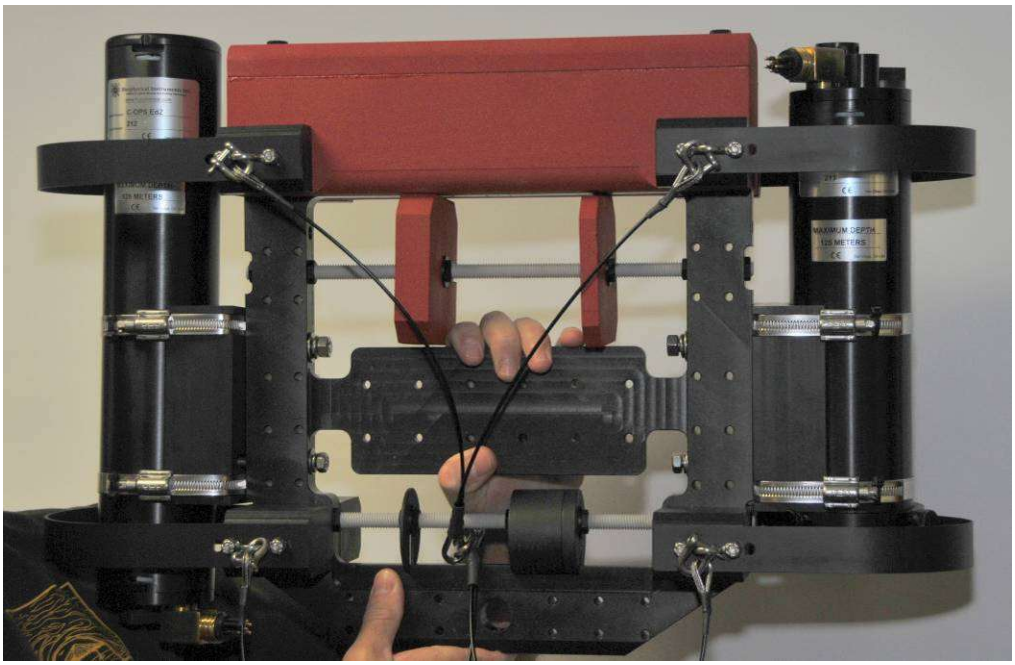

Figure 1) Biospherical C-Ops profiling system. At left is the Ed sensor, at right the Lu sensor. The red section is buoyant foam, with a cavity to place compressible or non-compressible flotation to slow the descent through the upper water column. Below are adjustable weights to trim the package. Disembodied hands for scale (picture from user's manual).

4) Data processing

4.1) Data analysis

The data were processed to level 2s using Matlab scripts. First, the start- and endpoints were identified by plotting the depth vs. time, and data with pitch or roll greater than 5 degrees were eliminated. Then, the depth offsets for both radiometers were applied and each sensor was binned to 10 cm. Means and standard deviation within each bin were calculated and are reported here. The upwelling sensor was merged to the downwelling sensor by depth, eliminating any L_u data greater than 0.25 meters from a corresponding E_d value.

Solar zenith angles were calculated from GPS data, and are included in the header file of each cast.

5) References

C-OPS manual, version 6. Supplied with instruments.

Morrow, J.H., C.R. Booth, R.N. Lind, and S.B. Hooker, 2010: “The Compact Optical Profiling System (C-OPS).” In: J.H. Morrow, S.B. Hooker, C.R. Booth, G. Bernhard, R.N. Lind, and J.W. Brown, Advances in Measuring the Apparent Optical Properties (AOPs) of Optically Complex Waters, NASA Tech. Memo. 2010–215856, NASA Goddard Space Flight Center, Greenbelt, Maryland, 42–50.

Zibordi, G., Berthon, J.-F., Mélin, F., D'Alimonte, D, “Cross-site consistent in situ measurements for satellite ocean color applications: The BiOMaP radiometric dataset”, Remote Sensing of Environment 115 (8) , 2104-2115, (2011).